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Vegetation Establishment on Reclaimed Coal Mine Spoils in Northwestern New Mexico[1]

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This study examined whether revegetation success obtained using irrigation during the first few years continued after irrigation was terminated. Vegetation variables were measured and compared among one undisturbed site and nine revegetated sites (three nontopsoiled and six topsoiled sites) of various ages from a mine near Farmington, NM. Mean percent foliar cover was significantly higher for the topsoiled sites than the nontopsoiled or undisturbed sites. All other mean vegetation variables from the reclaimed sites equaled those from the undisturbed site. Of the seeded grass species, alkali sacaton (*Sporobolus airoides*) had the greatest mean foliar cover and density in all of the topsoiled sites and most of the nontopsoiled sites; Russian thistle (*Salsola kali*) was the dominant invader in all sites; and fourwing saltbush (*Atriplex canescens*) was the dominant shrub in all sites. Similarity indexes indicated that the types of plants growing among the study sites were different. Overall, the mean vegetation variables from the reclaimed sites were equal to or greater than those from the undisturbed site regardless of treatment age. Even though most plant parameters decreased with age, mean totals of cover, density, and diversity for the oldest reclaimed sites equaled or exceeded suggested reclamation success guidelines.

Keywords: vegetation variables, reclamation, Southwest

Introduction

The feasibility of revegetating drastically disturbed coal-mined lands has been well documented by reclamation specialists throughout the semiarid Southwest (Aldon and Oaks 1982). Although revegetation success has been achieved using irrigation during the first few growing seasons, the question still remains as to whether the seeded plants will survive and perpetuate to form stable plant communities when irrigation is terminated.

The objective of this study was to determine seeding success and vegetation establishment on coal mine spoils in northwestern New Mexico. Several vegetation variables were measured, and plant species importance values and site similarity indexes were calculated from one undisturbed site and nine reclaimed coal mine sites of various ages.

Study Area

This study was conducted in 1986 on the San Juan Coal surface mine near Farmington, New Mexico. The dominant premining soil type was a moderately deep, course-textured soil developed over and from a sandy aeolian or alluvial sediment (Gould et al. 1977). The cli-

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mate was semiarid, with high diurnal temperatures and infrequent precipitation which averaged 16 cm annually from 1974 to 1985 with most received in the fall and winter.

An undisturbed, native vegetation reference area surrounded nine disturbed, reclaimed treatment sites. All treatment sites had been recontoured and seeded at least 3 years prior to study and ranged in age from 3 (1983) to 12 (1974) growing seasons. The three oldest, nontopsoiled disturbed sites were reclaimed by: (1) grading and leveling the overburden spoil (nontopsoiled), (2) mulching with 4.5 metric tons ha^{-1} of grass hay crimped 15 cm deep, (3) fertilizing with 72 kg ha^{-1} nitrogen (N) and 90 kg ha^{-1} phosphorus (P), (4) seeding with a mixture of four native plant species [galleta (*Hilaria jamesii* (Torr.) Benth.), alkali sacaton (*Sporobolus airoides* (Torr.) Torr.), Indian ricegrass (*Oryzopsis hymenoides* (R. + S.) Ricker) and fourwing saltbush (*Atriplex canescens* (Pursh) Nutt.], and (5) irrigating for two growing seasons.

The mine spoil sites reseeded between 3 and 8 years before measurement were reclaimed using the same amendment materials and revegetation techniques as described above, but differed in that stockpiled topsoil was placed 20–30 cm deep over the recontoured spoil. Six plant species were added to the mixture seeded in the older sites [sand dropseed (*Sporobolus cryptandrus* (Torr.) A. Gray), western wheatgrass (*Agropyron smithii* (Rydb)), streambank wheatgrass (*Agropyron riparium* Wats.), blue grama (*Bouteloua gracilis* (H.B.K.) Steud.), shadscale saltbush (*Atriplex confertifolia* (Torr. + Frem.) Wats.), and winterfat (*Ceratoides lanata* (Pursh) J. T. Howell)]. Soil chemical and physical properties were previously reported by Fresquez et al. (1986).

Site Measurements

Vegetation foliar cover, density, bare soil, and litter were measured for the ten sites using the Community Structure Analysis (CSA) method (Pase 1981), which incorporates a rated microplot (Morris 1973). Plant species foliar cover was based on one hundred 5- by 10-cm rated microplots per transect; three transects were sampled per site. Density estimates were based on the number of individual plant species per ten 0.5-m^2 circular plots per transect. Frequency was calculated from the proportion of the circular plots in which an individual species was present. An importance value (IV; maximum value = 3.0) was computed for each species from relative cover, relative density, and relative frequency.

The mean site variables were compared among the study sites using one-way analysis of variance. Tukey's multiple range test ($P \leq 0.05$) was used to compare sample means among the sites (Steel and Torrie 1960). A quantitative expression of plant diversity and treatment similarity for the ten sites was calculated using Shannon's index of species diversity and Sorensen's Community Coefficient from plant density data (Greig-Smith 1983), respectively.

Results

Foliar Cover

Mean percent foliar cover was significantly higher for the topsoiled sites than the nontopsoiled sites and the undisturbed site (figs. 1 and 2). In both the topsoiled and nontopsoiled sites, foliar cover generally decreased with reclamation age so that the oldest nontopsoiled site and the oldest topsoiled site had foliar cover equal to or greater than the undisturbed area. Grasses were the dominate life-form in most of the treatment-dates, followed by forbs and shrubs (fig. 1). Alkali sacaton and galleta dominated all but the two oldest treatments, and Russian thistle was a major invader in all but the youngest treatment.

Mean percent litter was statistically higher in the topsoiled sites (13.8%) than either the nontopsoiled (9.6%)

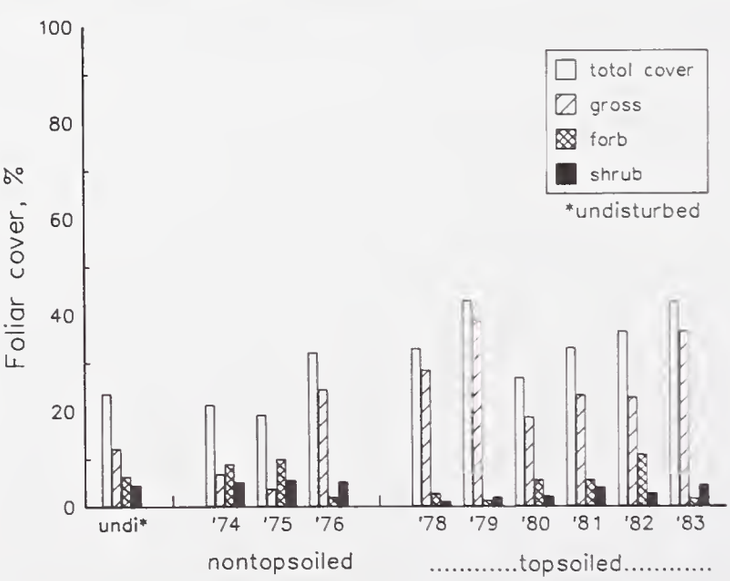

Figure 1.—Total mean percent foliar cover and life-form by treatment and date.

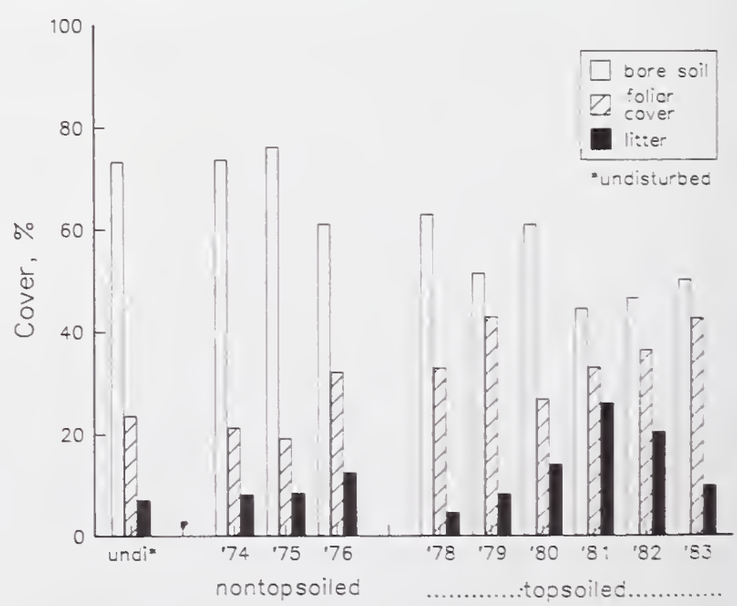

Figure 2.—Total mean percent bare soil, cover, and litter by treatment and date.

or undisturbed (7.0%) sites, and generally declined with treatment age (fig. 2). Mean bare soil was quantitatively less in the topsoiled sites and generally increased with treatment age (fig. 2). Mean foliar cover of fourwing saltbush was greatest in the nontopsoiled sites (4.2%) and lowest in the undisturbed site (2.3%) and generally declined with treatment age. Indian ricegrass apparently failed to germinate or establish on any of the reclaimed sites. In addition, streambank wheatgrass, sand dropseed, shadscale saltbush, and winterfat did not germinate or establish on the topsoiled sites.

Density, Diversity, Frequency, and Species Richness

In general, mean density (fig. 3), diversity (fig. 4), and species richness were quantitatively greatest in the topsoiled treatments, and differences were statistically significant for density. The undisturbed site and the topsoiled sites were dominated by galleta, alkali sacaton, and Russian thistle, while the nontopsoiled sites were dominated by Russian thistle and Kochia. The density of seeded species appeared to decrease and invaders increased with age. Western wheatgrass, blue grama, alkali sacaton, and Kochia dominated the youngest topsoiled site. Blue grama had the greatest density of all seeded species on the youngest topsoiled site, but apparently did not perpetuate itself in the older reclaimed areas.

The dominant seeded grass occurring in all of the topsoiled sites was alkali sacaton. In contrast, the nontopsoiled sites were generally dominated by nonseeded annual species, such as cheatgrass, mustard, Kochia, and Russian thistle.

The mean diversity was higher, but not statistically different on the reclaimed sites compared to the undisturbed site (fig. 4). The nontopsoiled and topsoiled sites were similar, and the oldest nontopsoiled (1.36) and topsoiled sites (1.59) had a greater diversity than the undisturbed site (1.22). Mean species richness was also greater in topsoiled treatments, but not statistically different. Richness declined slightly or remained stable with age.

Seeded species frequency was generally highest for the topsoiled sites. For example, alkali sacaton, galleta, and fourwing saltbush were more evenly distributed in the topsoiled sites (73%, 27%, and 47%, respectively), whereas galleta and Russian thistle were the most evenly distributed in the undisturbed sites (67% and 77%, respectively).

Importance Values and Similarity Indexes

Alkali sacaton had the greatest mean importance value (IV) (0.855) on all of the topsoiled sites and appeared stable between years, but declined on the nontopsoiled sites (0.186) to a level below the control (0.347). Russian thistle had the greatest mean IV (0.721) on the nontopsoiled sites and, along with cheatgrass, was a common invader on all sites. Galleta, Russian thistle, alkali sacaton, and broom snakeweed had the four highest importance values in the undisturbed site (1.048, 0.818, 0.347, and 0.205, respectively), while galleta was the second most important seeded grass species in all reclaimed sites. Blue grama ranked second in importance (0.693) on the youngest topsoiled site, but ranked lowest or was nonexistent in the other sites. Fourwing saltbush was the most important seeded shrub and was slightly more important on nontopsoiled (0.244) than on topsoiled (0.188) sites, but appeared to decline with reclamation age. The nontopsoiled sites were dominated by Russian thistle, cheatgrass, alkali sacaton, and Kochia; alkali sacaton, Russian thistle, galleta, and fourwing saltbush dominated the topsoiled sites.

Similarity indexes indicated that the nontopsoiled and topsoiled treatments were most similar (62%) based on

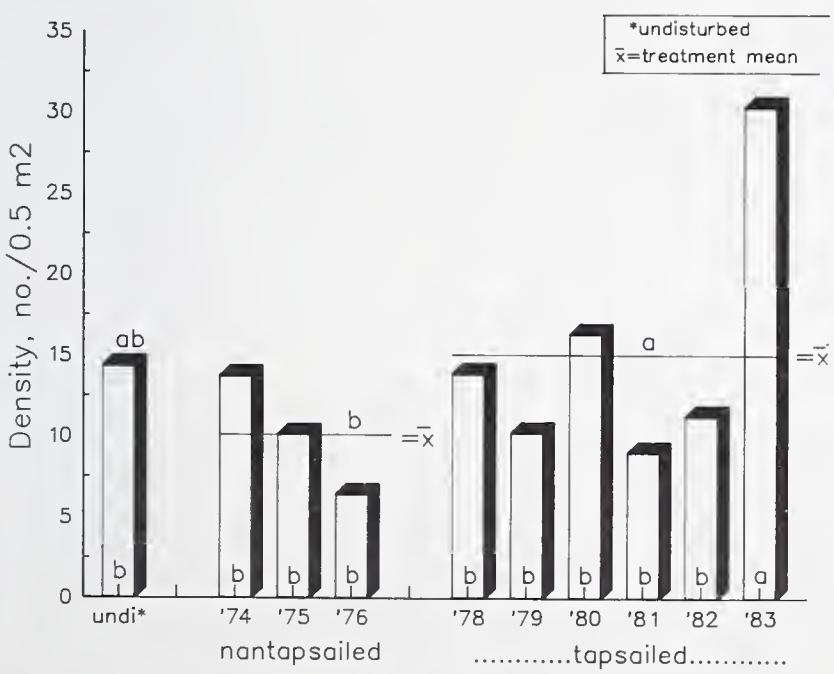

Figure 3.—Total mean density (all species) by treatment and date. Treatment mean ($\bar{x}$) and/or year with the same letter (a,b), are not significantly different at p = 0.05.

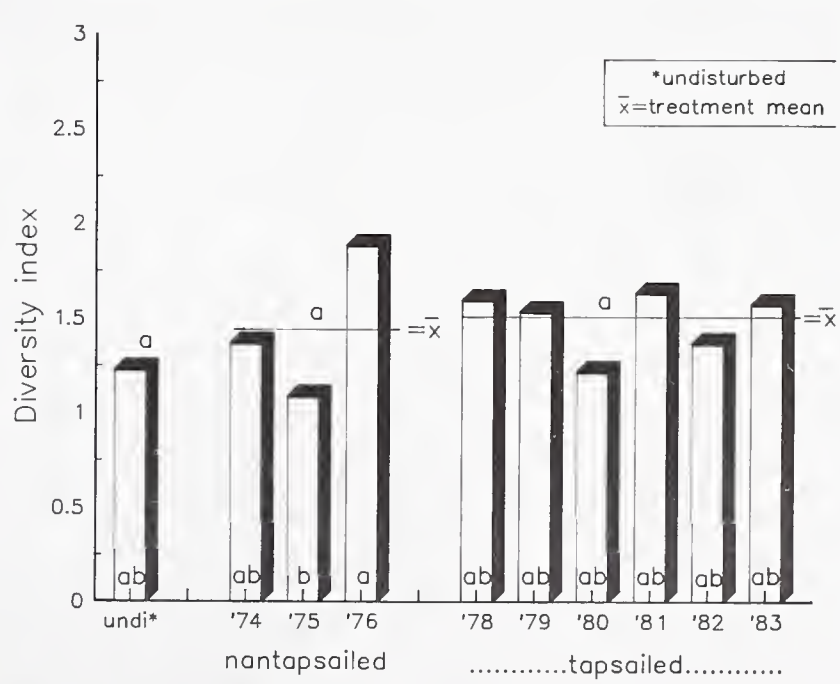

Figure 4.—Mean diversity by treatment and date. Treatment mean ($\bar{x}$) and/or year with the same letter (a,b), are not significantly different at p = 0.05.

species density, whereas the undisturbed and the nontopsoiled treatments were least similar (37%). However, similarity between the undisturbed and reclaimed areas appeared to increase with treatment age.

Discussion

Statistical differences in percent foliar cover, and quantitative differences in density, diversity, frequency, IV, and similarity indexes were observed among the undisturbed, and the reclaimed topsoiled and nontopsoiled sites. The reclaimed sites differed in the number of plant species seeded and in the characteristics of the spoil material and soils. Percent foliar cover of seeded species was statistically greater on the topsoiled sites than on the nontopsoiled sites apparently because of the differences in chemical and physical properties of the nontopsoiled spoil materials.

Grasses represented the dominant seeded plant lifeform on the topsoiled sites. This was the result of (1) greater seeding rates; (2) greater ability of grasses to germinate and compete; and (3) cultural techniques that favored grass establishment and survival.

The percent foliar cover of alkali sacaton and galleta was greater on the topsoiled sites than on nontopsoiled sites. Thus, it appeared that the abiotic conditions of the nontopsoiled spoil materials may have affected the establishment and survival of these two native seeded grasses. For example, the higher mean pH in topsoiled sites (7.5) compared to the nontopsoiled sites (6.8) apparently contributed to the dominance of alkali sacaton, which favors alkaline soils (Stubbendieck et al. 1981). The absence of Indian ricegrass on the reclaimed sites may have resulted from a failure to meet seed dormancy-breaking requirements (Zemetra et al. 1983).

Fourwing saltbush dominated two of the three nontopsoiled sites, and had a greater percent foliar cover on the nontopsoiled than the topsoiled sites. Fourwing saltbush has been shown to survive well on nontopsoiled spoil areas (Aldon 1984), and its dominance could have resulted from natural immigration (Wagner et al. 1978) and/or the lack of survival and resultant competition of the other seeded shrubs (Booth 1985). However, the topsoiled sites did not favor the germination of shadscale or winterfat.

Mean diversity of the reclaimed sites was quantitatively higher than that of the undisturbed site apparently because of open niche spaces and the resultant invasion of Russian thistle, cheatgrass, tansy mustard, Kochia, and other annuals. Because of poor establishment of seeded species on nontopsoiled sites and therefore less competition, growth of invaders on nontopsoiled sites was higher than on topsoiled sites. These results are similar to those found by Biondini and Redente (1986) in the Piceance Basin of Colorado.

The apparent trend of lower percent foliar cover with reclamation age indicates a reduction in available plant nutrients (Fresquez et al. 1986), soil moisture, and an increase in the competition between plants. Competition for abiotic resources and depletion of biotic resources may have become growth-limiting when the level of artificially provided nutrients and water fell below the critical level. In any case, it is apparent that most of the reclaimed site plant variables equaled or exceeded the undisturbed site, and the mean totals of cover, density, and diversity in the oldest reclaimed sites equaled or exceeded suggested reclamation success guidelines (Aldon 1984) when irrigation was terminated.

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